4.0 Conclusions and Judgments of Need

The accident investigation board determined that the direct cause of the explosion and resulting injuries was a disturbance (impact with a steel probe) of an unrecognized and unanalyzed shock-sensitive explosive compound (consisting of potassium superoxide and mineral oil) that was formed when mineral oil was inappropriately sprayed on a previous NaK spill.

As discussed throughout this report, there were 14 causal factors that contributed to the accident. The accident investigation board assessed the circumstances of the accident and the contributing causal factors and identified six root causes, which are included in Table 9. The Board's determination of the root causes used formal analytical techniques, including change analysis, barrier analysis, and events and causal factors analysis. The results of these analytical techniques are summarized in Appendix B.

The overall conclusion of the accident investigation board is that the explosion and subsequent injuries could have been prevented. Although some progress has been made in implementing ISM within the DUO organization, there were failures in management systems and ISM processes within OR and within every level of the LMES management chain. Because of these failures in the management system and ISM processes, there were numerous missed opportunities to prevent the December 1, 1999, spraying of NaK into the furnace and the December 8, 1999, explosion.

The accident investigation board also concluded that significant and prompt senior DOE and LMES management attention is needed to enhance worker protection by improving implementation of ISM and management systems. The Board has identified a set of judgments of need, which are included in Table 9.

Table 9. Root Causes and Judgments of Need

Judgments of Need	Root Causes
#1: Strengthen the training and competence for workers and for managers, engineers, and safety professionals responsible for worker safety. A. Strengthen training for workers, including sitewide workers, on specific hazards such as NaK through such means as hazard communication training and General Employee Training. B. Institutionalize unique hazards such as NaK, liquid metals, and superoxide into training programs and procedures, including tests and lesson plans. C. Conduct immediate training on NaK/superoxide for anyone entering the arc melt area, including hazard concerns, the incompatibility of mineral oil, emergency response, and fire fighting. D. Require managers, engineers, and safety professionals responsible for worker safety to obtain, maintain, and demonstrate competence in work-related hazards, material incompatibilities, and concerns. E. Incorporate hazardous material MSDSs, safety manuals, and other relevant information on lessons learned into training. F. Establish processes to assure that hazard training is in compliance with applicable OSHA and DOE requirements. G. Develop and implement a work area (job-specific) hazard communication training program at Y-12, and require supervisors to receive hazard communication training for supervisors.	LMES failed to establish, seek, or maintain an adequate level of knowledge and competence on the hazards associated with NaK, including the formation of superoxide, the incompatibility of superoxide and organics, and the explosive sensitivity of the mixture to impact or shock.
#2: Strengthen the implementation of the ISM core functions and existing LMES processes to assure that all potentially hazardous work and activities are subjected to effective, formal, and documented hazards analysis. A. Strengthen the process to assure that all potentially hazardous activities are subjected to formal and effective hazard analyses, including job hazard identification and JHAs. B. Eliminate any loopholes that would bypass formal hazard analyses, including classifying a job as "routine" maintenance. C. Revise the authorization basis for the potassium superoxide hazard and expedite review and approval of the BIO by DOE. D. Conduct a USQD on current conditions in the arc melt area to assure adequate compensatory safety measures and control of recovery. E. Require MSDSs and other relevant hazards information to be incorporated into hazard analysis and control processes. F. Significantly strengthen the USQD process to include formal analysis and documentation; involvement of appropriate technical expertise; assessment of activity, controls, and safety information and MSDS; and management review and approval. G. Establish a process to assure that when a unique hazard such as superoxide is identified in the safety analysis for one facility, it is appropriately considered and incorporated into the authorization basis and hazard analyses for other facilities with the same hazard. H. Strengthen the management and independent QA oversight of hazard analysis and control processes. I. Ensure that fire protection engineering is involved in hazard analyses for work with the potential for a fire or explosion. J. Incorporate "welding-like" hazards (e.g., molten metals) into hazard identification and analysis.	LMES's implementation of the hazard analysis and control processes failed to identify, prevent, or mitigate the explosive interaction of potassium superoxide, mineral oil, and impact. The NaK Material Safety Data Sheet was not used.

Table 9. Root Causes and Judgments of Need (Continued)

Judgments of Need	Root Causes
#3: Strengthen the identification and implementation of engineering, administrative, and worker protection controls for potentially hazardous work and activities. A. Strengthen the implementation of the OSB process by involving senior management and applying the process to all hazardous activities and procedures. B. Strengthen the procedure development, verification, and validation processes to assure technically accurate and useable procedures. C. Strengthen engineering resources for maintaining and documenting facility configuration, including accurate as-built piping and instrument drawings. D. Strengthen implementation of ISM to assure that only approved mechanisms or procedures are used to control potentially hazardous work and activities. E. Strengthen the control over the categorization of procedures by involving the OSB and senior management to assure that the categorization is appropriate to work complexity, hazards, and frequency of performance. F. Strengthen the management and independent QA oversight of the hazard control process to assure continuous adherence to established processes and improvement. G. Review and analyze the basis and priorities associated with the failure to maintain funding for the completion and startup of a safer melting system as a lessons-learned commitment from the 1992 NaK release. H. Utilize the DOE hazard control prioritization hierarchy with engineering controls as a first priority, administrative controls as a second priority, and PPE as the priority of last resort. I. Evaluate and correct any fire protection detection deficiencies that prevented a fire or smoke alarm following the NaK explosion. J. Improve pre-job briefings to assure that hazards, hazard controls, and PPE are adequately addressed and understood.	LMES management systems and processes did not assure adequate procedures or controls to prevent the loss of system configuration control resulting in an NaK spill or to preclude the addition of mineral oil and impact in the presence of potassium superoxide during NaK spill recovery.

Table 9. Root Causes and Judgments of Need (Continued)

Judgments of Need	Root Causes
#4: Strengthen the implementation of the ISM feedback process through the improved sharing of technical expertise and information and through use and appropriate application of lessons learned from events, accidents, and near misses. A. Ensure adequate research or communication with experts when conducting hazards assessments, developing or revising authorization basis, or conducting unique or hazardous operations, or when unusual or unexpected conditions are encountered. B. Significantly improve LMES corporate and site response to lessons learned from Y-12 and other sites by including broader application, tracking and implementation, and upgrading of management systems, processes, programs, and ISM core functions as warranted. C. Significantly improve the incorporation of lessons learned, corrective actions, and commitments into programs, policies, procedures, and training materials. D. Establish a process to assure that commitments or corrective actions resulting from events and accidents are not deleted from programs, processes, or procedures during subsequent revisions. E. Establish an independent corporate LMES panel to review and evaluate common causal factors between the last six Type A accident investigations at Lockheed Martin sites and the implications for ISM and key processes such as procedure quality and use, hazard analysis and controls, application of skill of the craft, system configuration control, control of routine work, training, management involvement, and QA.	LMES management failed to effectively communicate or utilize information from the hazard screening evaluation, lessons learned, previous events and accidents, studies, analyses, and publications in planning and controlling this work and the associated hazards to worker health and safety. Knowledge of this hazard and expertise to address it were readily available at the Oak Ridge Reservation and other DOE sites.

Table 9. Root Causes and Judgments of Need (Continued)

Judgments of Need	Root Causes
#5: Expedite the understanding, acceptance, and implementation of the ISM core functions through improved use of and adherence to work and hazard controls, including procedures. A. Require all hazardous, complex, or infrequently conducted work and activities (including maintenance) to be conducted with procedures in hand, step-by-step, and in proper sequence. B. Strengthen system configuration control through increased use of step signoffs, valve alignment checklists, or independent verification for key steps that could impact the safety of workers or the public. C. Ensure the review and adherence to all applicable procedure prerequisites, precautions, limitations, cautions, and warnings. D. Ensure that when procedures are not correct or will not work as written, or when unusual conditions are encountered, work is stopped and management and technical assistance sought for ANY procedure changes before proceeding. E. Establish and communicate a stronger LMES policy on use of and adherence to procedures and other work and hazard controls, including accountability mechanisms. F. Strengthen management and supervisory field presence and independent QA assessments to improve use of and adherence to controls, including procedures. G. Ensure that abnormal events are reported to LMES senior management and OR, and via the Occurrence Reporting and Processing System per DOE requirements. H. Ensure that abnormal conditions are fully investigated via the critique process to thoroughly determine the cause and corrective action, and ensure that corrective actions are verified to be complete and effective. I. Strengthen implementation of conduct of operations, including operating practices, communications, abnormalities, investigation, notification, configuration control, and procedures. J. OR and YSO need to strengthen line management oversight and increase field presence to ensure effective implementation of ISM.	OR, YSO, and LMES have not established or assured a safety culture that implements an ISM process in which workers are consistently held accountable for adherence to procedures and hazard controls and are willing to stop work and seek management and technical assistance when procedures do not work or abnormal conditions are encountered.

Table 9. Root Causes and Judgments of Need (Continued)

Judgments of Need	Root Causes
#6: Improve the identification, availability, and use of appropriate personal protective equipment to protect workers against work-related hazards. NOTE: This provision has been a factor in the last three Oak Ridge Type A accident investigations. A. Ensure the availability of essential PPE through effective procurement, distribution, storage, and inspections and testing. B. Strengthen the coordination between safety professionals, including industrial safety, industrial hygiene, health physics, and fire protection engineering, in identifying necessary PPE. Consider using a common form or permit to designate PPE. C. Strengthen processes to assure that lessons learned and corrective actions for PPE related to previous events or accidents are tracked and appropriately applied to similar work or hazards. D. Ensure adequate research, use, and adherence to PPE recommendations or requirements as defined by MSDSs, OSHA, LMES policies, the National Fire Protection Association, and DOE. E. Establish and implement a more formal, rigorous, and documented process for selection of PPE, including the type of respirators. The process should include full analysis of the hazards and compliance with requirements and regulations. F. Ensure that personnel are property trained and physically qualified to utilize PPE, including NaK suits and respirators, for work-related hazards and emergency response. G. Strengthen the oversight of the availability, selection, and use of PPE by management, QA, and safety professionals. H. Ensure that PPE requirements for work activities are clear, consistent, and unambiguous in work documents (RWPs, JHAs and procedures). I. Prior to performing a work activity, verify that all PPE has been assigned and is available, and that workers have been briefed on the use, precautions, limitations, and prerequisites of the prescribed PPE.	LMES management systems and processes were not effective in assuring the provisions for and use of appropriate personal protective equipment for working with a pyrophoric liquid metal and protecting against thermal and caustic chemical burns and the inhalation of toxic and radioactive smoke.